CLAIMS

What is claimed is:

1. A method for manufacturing a sensor for measuring angular velocity in a sensing plane, the method comprising:

a) etching a sensing subassembly from a gyroscope wafer, the subassembly comprising:

i) a substantially planar frame parallel to said plane; and

ii) a linkage connected to said frame and comprising a first mass and a second mass laterally disposed in said plane and constrained to move in opposite directions perpendicular to said plane;

b) providing an actuator for driving a first portion of said subassembly into oscillation at a drive frequency; and

c) providing a transducer for sensing motion of a second portion of said subassembly responsive to said angular velocity.

2. The method of claim 1, wherein said providing an actuator comprises providing an actuator selected from the group consisting of electrostatic actuators, electromagnetic actuators, piezoelectric actuators, and thermal actuators.

3. The method of claim 1, wherein said providing a transducer comprises providing a transducer selected from the group consisting of capacitive sensors, electromagnetic sensors, piezoelectric sensors, and piezoresistive sensors.

4. The method of claim 1, wherein said first portion of said subassembly is said linkage and said second portion of said subassembly is said frame.

5. The method of claim 1, wherein said first portion of said subassembly is said frame and said second portion of said subassembly is said linkage.

6. The method of claim 1, wherein said etching a sensing subassembly further comprises etching a hole in at least one of said masses to reduce air resistance.

7. The method of claim 1, wherein said etching a sensing subassembly comprises high aspect ratio etching.

8. The method of claim 7, wherein said high aspect ratio etching comprises deep reactive ion etching.

9. The method of claim 1, further comprising thinning said gyroscope wafer prior to said etching a sensing subassembly.

10. The method of claim 9, wherein said thinning comprises grinding and polishing.

11. The method of claim 9, wherein said thinning provides a gyroscope wafer having a thickness of about 40 microns.

12. The method of claim 9, wherein said thinning comprises selectively thinning said gyroscope wafer to at least two different thicknesses, such that said masses defined by

said etching have the larger of said two different thicknesses.

13. The method of claim 1, further comprising photolithographically patterning said gyroscope wafer to define said subassembly prior to said etching.

14. The method of claim 1, further comprising:

etching a substantially planar base from said gyroscope wafer, said base being parallel to and positioned around said frame; and

reference bonding said base to a top surface of a reference wafer;

wherein said providing an actuator comprises depositing a plurality of control electrodes on said top surface of said reference wafer, and

wherein said providing a transducer comprises depositing a frame electrode connected to said frame and depositing a base electrode connected to said base, wherein said frame and base electrodes comprise a capacitive sensor.

15. The method of claim 14, wherein said reference bonding is selected from the group consisting of Al-Ge bonding, solder bonding, In-Au bonding, eutectic alloy bonding, and polymer bonding.

16. The method of claim 14, further comprising fabricating CMOS circuitry within said reference wafer.

17. The method of claim 16, further comprising connecting said circuitry to said plurality of control electrodes, and

connecting said circuitry to said capacitive sensor, whereby wafer scale integration of said actuator and said transducer is obtained.

18. The method of claim 16, further comprising depositing a sense electrode connected to said circuitry and positioned on said top surface of said reference wafer for sensing motion of said linkage relative to said reference wafer.

19. The method of claim 14 further comprising etching two recesses into said top surface of said reference wafer, said recesses being aligned with said first and second masses to accommodate motion of said masses perpendicular to said sensor plane.

20. The method of claim 14, wherein said etching a sensing subassembly further comprises:

etching a center plate connected to said frame and connected to and in between said first and second masses;

etching a first edge plate connected to said frame and to said first mass; and

etching a second edge plate connected to said frame and to said second mass;

wherein said plates are rotatable about parallel axes of rotation which are also parallel to said sensor plane, and

wherein said linkage further comprises said center plate and said first and second edge plates.

21. The method of claim 20, wherein said etching a sensing subassembly further comprises:

etching a first pair of torsional flexures connecting said center plate to said frame;

etching a second pair of torsional flexures connecting said first edge plate to said frame; and

etching a third pair of torsional flexures connecting said second edge plate to said frame.

22. The method of claim 20, wherein said etching a sensing subassembly further comprises etching a hole in at least one of said plates to reduce air resistance.

23. The method of claim 20, wherein said depositing a plurality of control electrodes comprises:

depositing a first edge split electrode positioned beneath said first edge plate on said top surface of said reference wafer and separated from said first edge plate by a predetermined distance d;

depositing a second edge split electrode positioned beneath said second edge plate on said top surface of said reference wafer and separated from said second edge plate by the distance d;

depositing a center split electrode positioned beneath said center plate on said top surface of said reference wafer and separated from said center plate by the distance d.

24. The method of claim 23 further comprising depositing a standoff on said top surface of said reference wafer to define said distance d.

25. The method of claim 23 further comprising etching a standoff on said base to define said distance d.

26. The method of claim 20, wherein said etching a center plate further comprises etching a first lever arm connected to said first mass and etching a second lever arm connected to said second mass, whereby motion of said masses perpendicular to said sensor plane responsive to rotation of said center plate is increased.

27. The method of claim 20, wherein said etching a first edge plate further comprises etching a lever arm connected to said first mass, whereby motion of said first mass perpendicular to said sensor plane responsive to rotation of said first edge plate is increased.

28. The method of claim 20, wherein said etching a second edge plate further comprises etching a lever arm connected to said second mass, whereby motion of said second mass perpendicular to said sensor plane responsive to rotation of said second edge plate is increased.

29. The method of claim 14, further comprising etching a plurality of flexures connecting said base to said frame.

30. The method of claim 29, wherein said etching a sensing subassembly further comprises etching a groove in a surface of said frame facing said base, and wherein said etching a substantially planar base further comprises etching a tab extending from said base toward said frame and engaged in said groove, the combination of said tab and said groove

restricting the range of motion of said frame, thereby protecting said flexures.

31. The method of claim 14, further comprising

etching a plurality of flexures connecting said frame to said reference wafer; and

etching a plurality of base isolation trenches separating said flexures from said base;

whereby stress in said base is not coupled to said flexures.

32. The method of claim 31 further comprising

etching a plurality of reference isolation trenches separating said flexures from said top surface of said reference wafer,

whereby stress in said top surface of said reference wafer is substantially not coupled to said flexures.

33. The method of claim 14, further comprising cap bonding said base to a bottom surface of a Silicon cap wafer.

34. The method of claim 33, wherein said cap bonding is selected from the group consisting of glass bonding, gold eutectic bonding, solder bonding, Si to Si fusion bonding and Si to SiO_2 fusion bonding.

35. The method of claim 33, wherein said cap bonding is performed at an equal or higher temperature than said reference bonding, and wherein said cap bonding is performed prior to said reference bonding.

36. The method of claim 33 further comprising etching a recess into said bottom surface of said cap wafer to accommodate motion of said sensing subassembly.

37. The method of claim 33, wherein said cap bonding comprises a first hermetic bonding and wherein said reference bonding comprises a second hermetic bonding, thereby providing a hermetic enclosure surrounding said sensing subassembly.

38. The method of claim 37, further comprising changing a pressure within said hermetic enclosure to be substantially different from atmospheric pressure.

39. The method of claim 37, wherein said first hermetic bonding comprises a first eutectic metal sealing, and said second hermetic bonding comprises a second eutectic metal sealing.

40. The method of claim 33, further comprising:

etching a plurality of flexures connecting said frame to said cap wafer; and

etching a plurality of base isolation trenches separating said flexures from said base;

whereby stress in said base is not coupled to said flexures.

41. The method of claim 40 further comprising

etching a plurality of cap isolation trenches separating said flexures from said bottom surface of said cap wafer,

whereby stress in said bottom surface of said cap wafer is substantially not coupled to said flexures.